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SELECTION OF LOADING AND HAULING EQUIPMENT: USER PRACTICES

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March 1988

For presentation at the 21st APCOM conference, Las Vegas, Nevada, February 27 - March 2, 1989.

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15 pp

COAL RESEARCH LABORATORIES

DIVISION REPORT CRL 88-24 (OP,TR)

MICROMEDIA

88-06050/

SELECTION OF LOADING AND HAULING EQUIPMENT: USER PRACTICES

by

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ABSTRACT

This paper deals with the problem of efficiently selecting the most appropriate loading and hauling equipment for surface mines. Problems and factors that affect productivity and operating cost are identified.

During the course of collecting the information for this study, mining companies and equipment manufacturers were interviewed to define their selection practices. The majority of mining companies prepare general specifications and ask the suppliers to mate those specifications to their product line. The mining company then evaluate various proposals on the basis of the best available deal.

The following mines from western Canada provided information for this study: Coal Mountain, Line Creek, Quintette, Westar's Harmer mine from the Province of British Columbia, and Coal Valley, Gregg River, Highvale, Luscar from the Province of Alberta.

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SÉLECTION D'UN APPAREIL DE CHARGEMENT ET DE TRANSPORT : MODES DE SÉLECTION DES USAGERS

par

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RÉSUMÉ

Le présent rapport traite du problème que pose la sélection de l'appareil le plus approprié au chargement et au transport dans les mines à ciel ouvert. Les problèmes et les facteurs qui touchent à la productivité et aux coûts d'exploitation sont identifiés également.

Dans le cadre de cette étude, au cours de la collecte d'informations, on a consulté des représentants de sociétés minières ainsi que des fabricants d'équipement afin de définir leurs modes de sélection. La plupart des sociétés minières élaborent des spécifications et demandent aux fournisseurs de combiner ces spécifications à leur produit. La société minière étudie par la suite diverses offres présentées en se basant sur la meilleure offre disponible.

Les mines de l'Ouest canadien suivantes ont fourni des renseignements dans le cadre de cette étude : Coal Mountain, Line Creek, Quintette, et Harmer de la Westar de la province de Colombie-Britannique, et les mines Coal Valley, Gregg River, Highvale et Luscar de la province de l'Alberta.

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INTRODUCTION

This overview is an insight into the logic used by mining companies and truck manufacturers to select loading and hauling equipment. The selection process for loading and hauling equipment is explained, and an overview of selection practices used by mining companies is provided. It may be seen from this overview, that selection often concentrates only on hauling equipment. Loading equipment is selected by simple calculation of the time needed to remove the material and by matching the equipment to the mining conditions (e.g. number of mining faces, material characteristics, weather, movability of the equipment). However, the personal knowledge and experience of the mine engineer or manager with the loading equipment is the major influence. Most mining companies leave the selection of hauling equipment to truck manufacturers and evaluate their proposals on the basis of the best available deal. Again, personal experience and knowledge of the line of equipment offered, is often paramount in the truck selection process.

SELECTION OF LOADING EQUIPMENT

General

The selection criteria and practices presented here are for front-end loaders, hydraulic excavators and power shovels, which are commonly used at the Canadian coal mines selected for this study. Other equipment, such as draglines, bucket wheel excavators, scrapers, dozers, and continuous miners have other specific applications.

The objective of this study was to determine selection practices for standard "load-haul-dump" systems. While other types of equipment are also used by mining companies elsewhere, their inclusion in the study was not considered practical.

In general, loading equipment must satisfy the following requirements:
- -be used for loading coal or waste from "coal zone" only, ("Coal zone" is defined as coal seam with the partings in prairie deposits, coal seams with interburden waste, or waste around undulating coal seams in mountain deposits.),
- -be accepted by most mines under study, and
- -have performed satisfactorily at selected mines for an extended period of time.

Power Shovels

The power shovels are divided into two major groups by their application:
- -stripping, and
- -loading.

The main difference between these two types is the size with stripping shovels being the larger unit. Stripping shovels are not included in the study, because they are not used at Canadian mines (large draglines and/or truck/shovel systems are used for removing the overburden).

The loading shovels in the selected mines are manufactured by three companies: Demag Lauchhammer, Bucyrus-Erie and Harnischfeger P&H.

Loading shovels are generally used in more severe digging conditions than other equipment; they are suited for multi-shift mining operation, for coal or waste loading and tend to have more long range application than other loading equipment. A typical operating cycle consists of a digging cut, a loaded swing to the discharge area, dumping, and an empty return swing to the digging face. The average swing angle is between 70 to 120 degrees and the cycle time is 25 to 35 seconds.

There have been considerable design changes to shovels during the last twenty years, especially in the drive system, mechanical configuration variations, and so on. The major differences for each of the powered functions are quite extensive and are beyond the scope of this study. All new developments in machine design will ultimately lead to improved performance and higher productivity. Some design features are common for all applications, some are customized for particular mining operations.

Electric loading shovels are generally selected for severe mining conditions and continue to be the standard against which other units are compared. Their mechanical availability and high production output meet the needs of fairly large mines. Digging cycle times are comparable to other types of loading equipment. They are usually selected for mine sites with sufficient reserves to sustain production for an extended period of time. Electric shovels cannot be readily disassembled and moved to other sites, because of their size. The machines may be quite easily relocated around the pit to meet blending requirements or changes in mine plan. Frequent, long distance moves are not desirable.

Shovels have relatively low ownership and operating costs. Estimates of production and of the cost of operation depends on detailed site conditions and manufacturers will provide these estimates for stated conditions, based on their experience in similar applications. These estimates are generally based on average data extrapolated to meet anticipated average site conditions over the life of the operation. The variation in these averages can be substantial. Production factors included in such calculations are: material swell, material density, dipper size, digging conditions, swing angle, loading conditions, operator efficiency, machine availability, and operating schedule. Cost factors include: capital cost, freight charges,field erection, ballast, projected machine life, interest, insurance, taxes,power consumption, oils,greases, teeth and cables, crew wages, and maintenance.

There are several design options that vary with the manufacturers and depend upon the model selected.

Hydraulic Excavators

Three manufacturers have supplied hydraulic excavators to the studied mines in western Canada. They are: Mannesmann Demag, Caterpillar, and Hitachi.

The typical unit is offered in both shovel and hoe configurations. The designs differ in the orientation of the bucket and in front-end geometry. Typical units have the following features:

Hydraulic hoes:
-sizes from 2 to 16 m^3,
-powers from 220 to 1,800 kW,
-machine weights from 50,000 to 420,000 kg.

Hydraulic shovels:
-sizes from 2 to 30 m^3,
-powers from 220 to 1,800 kW,
-machine weights from 52,000 to 420,000 kg.

Both types are crawler mounted, have full revolving upper works, and are all hydraulically driven with low profile machinery compartments. The machines are employed in overburden/interburden removal, coal loading, and for general utility work.

Hydraulic shovels are flexible for digging, because the digging path is controlled. The general characteristics are:

Hydraulic hoes:
-maximum digging heights from 6 to 17 m,
-maximum digging depths from 6 to 17 m,
-maximum dumping heights to 12 m, and
-maximum reach at dumping from 6 to 11 m.

Hydraulic shovels:
-maximum digging heights from 9 to 15 m,
-maximum digging depths from 2 to 5.5 m,
-maximum dumping heights to 11 m, and
-maximum reach at dumping from 4.5 to 10 m.

Hydraulic excavators are selected where digging conditions are not so severe. Consolidated material must be blasted to maintain acceptable productivity with these machines. A typical application would be to load trucks or a mobile hopper with occasional moves of the machine to different digging faces within the pit area.

Selection of the hoe or shovel configuration is based on site conditions and the mine plan. The shovel appears to be capable of higher production under more difficult digging situations. Specific units must also be checked against the trucks to be used to confirm range limit and avoid size mismatching.

Equipment manufacturers will usually supply production calculations and cost estimates. These estimates, for stated conditions, are prepared by their technical representatives. The spread in the averages for the site conditions are substantial and the correction factors introduced require a considerable amount of judgement. Some of the considerations used in the calculations are listed below.

Production: material swell and density, bucket size and fill factors, job efficiency, swing angle, operational delays, operating schedule, and machine stability.

Cost: machine price, salvage value, machine life, interest, insurance, taxes, fuel consumption, lube, oil, grease, filters, operator wages, and maintenance.

Front-End Loaders

Front-end loaders are extensively used at all of the selected coal mines. The manufacturers are Letourneau, Dart, Caterpillar, and Terex. Their main utilization is in excavating, loading, and transporting of material. For mining applications, the trend has been towards larger, wheel mounted units in sizes above 5 m^3. During the last ten years, loaders have become primary production machines at some mine sites, excavating in medium to tough conditions, and loading up to 154 t trucks. The loaders used at mine sites have the following similar design features:

-articulated frame for 70 to 90 degree steering,
-four wheel drive,
-one or two diesel engines,
-mechanical or electric drive train,
-capacities from 2.5 to 23.0 m^3, and
-power from 130 to 950 kW.

Crawler mounted loaders are usually smaller than 4.0 m^3 bucket size and are not used as excavators at the mine face but are frequently used for utility work.

The articulated frame and rubber tires give the machine excellent maneuverability. The loaders used for truck loading may travel some distances from face to the truck and therefore may be employed where access to the face is restricted. During direct spoiling or loading operations, loaders may travel considerable distances. The loader is considered to be a competitive excavator, loader and transporter. It is preferable to shovels, dozers and, over short transport distances, to scrapers and trucks. It is a fast, highly mobile and versatile mining tool, that can be used in a number of mine applications.

Loaders have limited digging ability in consolidated digging faces and are more commonly used in softer formations, coal loading or general stockpile work. The primary mine applications are loading and/or transporting topsoil, coal from the face and stockpile, overburden and vaste handling. They are used to load trucks, hoppers, railroad cars or conveyor belts. The material may be transported for distances up to 300 m on level surfaces or grades up to 12 %. Loaders are also used for pit clean-up, boulder removal, road maintenance and snow removal, and general utility work.

Front-end loaders have the following advantages and limitations:

Advantages:
-wide bucket can handle large pieces,

-good blending capabilities at working face,
-leaves clean floor,
-no auxiliary equipment required,
-moderate dust generator,
-dumping action is easy on trucks, and
-good cutting efficiencies in medium bench heights (2 to 7 m).

Limitations:
-blasting or ripping of consolidated material required,
-considerable maneuevering space required,
-reduced performance on wet, soft ground surfaces,
-high tire wear,
-limited ability to deposit material deep into the truck or hopper,
-reduced stability in load and carry position,
-relatively poor visibility rearward,
-operator may be exposed when working high faces, and
-relatively high operator fatique.

Digging and dumping heights may be extended by using a special long boom which reduces the maximum bucket load.

Large machines are more rugged with increased power, and perform better in hard digging conditions. However, the relative carrying capacity, wheel base and travel speeds do not improve with size, indicating that there is no added advantage to increase the size of the loader. The productivity in a load-and-carry service is not improving.

From mining operations experience, loaders are usually selected larger in size than needed, because of their relatively low capital cost. In this case the loaders do not limit overall production.

Production is usually estimated by the manufacturer. The estimates are correlated with detailed site conditions and matched to the specific machine performance characteristics. Some of the factors considered are:

Production: material svell and density, bucket size, machine payload, digging conditions, loading arrangements, grades, rolling resistance, travel distance, maximum speeds, job efficiency, machine availability, and operating schedule.

Cost: machine price and life, salvage value, interest, insurance, taxes, fuel and lube/grease consumption, operator wages, tire cost, cutting edges, and maintenance.

Before a machine is selected, decisions are required on a number of options, such as: tires size, manufacturer, ply ratings, tread, engine type and size, differencial type, alternator capacity, bucket size and purpose, bucket teeth, cutting edges, lift arms usage, and counterweights.

SELECTION OF HAULING EQUIPMENT

General

Trucks from the following manufacturers are used in western Canada: Caterpillar, Euclid, Terex, Unit Rig, Kress, Wabco, and Kenworth.

Truck sizes vary from 32 tonnes for Caterpillar trucks at Highvale mine to a 317 tonne Titan employed at the Westar's Balmer mine. In this section of the study, trucks are not divided into categories as in the case of the loading equipment, because the selection practices are similar for rear dump or bottom dump trucks, articulated haulers, or mechanical/electrical drive trucks. The selection practice variances are tied to the production requirements, mining plan, life of the mine and projected usage of the hauling equipment.

Trucks

The primary operating differences between the rear dump and bottom dump trucks centers around the choice of the dumping method and are as follows:

Rear Dumps:
- -generally two axle units, one steering, one driving (3 axles on large trucks or on smaller articulated units, one steering, two driving),
- -single axle converter or two wheel electric drive systems,
- -rigid frame with heavy duty body,
- -front axle steering,
- -single wheels on front axle, dual wheels on rear axle,
- -capacities from 30 to 317 tonnes,
- -powers from 300 to 2240 kW, and
- -empty vehicle weights from 26,000 to 235,000 kg.

Bottom Dumps:
- -tractor-trailer with 3 axle units (one steering, one driving, one trailing),
- -various combination of single or dual wheels,
- -single axle torque converter or two wheel electric drive systems,
- -capacities from 70 to 180 tonnes,
- -povers from 310 to 1080 kW, and
- -empty vehicle weights from 40,000 to 105,000 kg.

Two axle bottom dump trucks are built only by Kress and are used extensively at the Highvale mine. These trucks are considered to be of superior quality and of higher than average performance.

Bottom dump hauling units are utilized to feed a grizzly, positioned on a ramp or at ground level, feeding a hopper. A back-in hopper station is utilized with rear dump trucks. The rear dump trucks are employed to haul heavy material, while the bottom dumps carry free flowing material such as coal. Following are the design features of both types (Martin et al, 1982):

Rear Dumps:
- -average payload to net vehicle weight ratio is approximately 1.45,

-average gross vehicle weight to power ratio of about 350,
-average power per ton of capacity ratio of about 9.5,
-high power and gradeability while loaded,
-a turning radius equal up 1.2 times of overall length,
-a rugged body designed to withstand high loading impact,
-forward mounted engine,
-mechanical drive system to 130 tonnes,
-electrical wheel drive systems from about 85 to 200 tonnes,
-electrical axle drive systems from 200 to 317 tonnes,
-unit body construction, and
-rear axle dual wheel drives.

With the two axle units, the front axle will carry approximately 47 % of the net weight of the load and 32 % of the gross weight. The rear axle will carry 53 % of the net weight and 68 % of the gross weight.

In the 3-axle unit, the front axle will carry approximately 36 % of the net weight of the load and 20 % of the gross weight. The rear axles will carry 64 % of the net weight and 80 % of the gross weight.

Bottom Dumps (two axle):
-average payload to net vehicle weight ratio of 1.7,
-average vehicle weight to power ratio of 150,
-average power per tonne of capacity ratio of 7.6,
-medium gradeability while loaded,
-a turning radius to overall length ratio of 0.63,
-clam-shell bottom discharge doors designed for free flowing material which cannot withstand impact loading,
-unit body construction,
-average width 6.0 m, and
-average loading height of 4.5 m.

The front axle will carry approximately 42 % of the net weight of the load and 47 % of the gross weight. The rear axle will carry approximately 58 % of the net weight and 53 % of the gross weight.

Bottom Dumps (three axle):
-average payload to net vehicle weight ratio of 1.6,
-average gross vehicle weight to power ratio of 500,
-average power per tonne of capacity ratio of 6.5,
-limited gradeability to 6 %,
-limited acceleration capability,
-a turning radius of 1.8 times overall length,
-lower tire loading,
-forward mounted engine,
-articulated tractor-trailer design with dual wheel drive on rear axle,
-mechanical drive system to 145 tonnes,
-electrical drive system from 110 to 160 tonnes,
-average width 5.0 m, and
-average loading height about 4.0 m.

The front axle will carry approximately 29 % of the net weight of the load and 15 % of the gross weight. The rear tractor axle will carry approximately 37 % of the net weight and 40 % of the gross weight. The trailer

axle will carry approximately 34 % of the net weight and 45 % of the gross weight.

The truck performance and economy are tied closely to haul road quality factors, such as grades, curve radius, width of the road, surface condition, and number of crossings. These are functions of the mine's operational practices. Top speed is often limited by safety, traffic, visibility, weather, and tire heating. The excavator must be matched to the truck with respect to size and capability to deposit the load in the truck body.

The type of truck selected for the site conditions and mine requirements depends on the following:
-material characteristics, its abrasiveness, density, swell, size,
-loading equipment reach, discharge severity,
-haul route requirements, grades, distances, curves,
-manouevering space, turning radius, and
-dumping conditions.

Truck specifications must include:
-capacity of the truck,
-engine power and manufacturer,
-drive gear ratios for mechanical drives,
-two axle or three axle configuration,
-mechanical or electrical drive system, and
-tire sizes, tread and ply rating.

Truck manufacturers usually supply performance charts for each model, shoving the rimpull requirements for various combinations of vehicle veight and effective grade, and the vehicle speed vs. rimpull. The vehicle speed can also be established from the chart data under retarding conditions. The projected truck production is calculated and estimates of the cost of the ownership are provided by manufacturers. Some of the production and cost factors entering into these calculations are:

Production: material swell and density, road grades and rolling resistance,travel distance, curves, anticipated traffic and maximum speed, job efficiency, mechanical availability, engine power, transmission characteristics, loading system, delays, and dump arrangement.

Cost: machine price and salvage value, projected life of the machine, interest, insurance and taxes, fuel, oil and grease, tire cost, maintenance, and operator wages.

During the selection process, the following is considered as a general guide:
1. Productivity per hour increases with truck size,
2. Productivity in [t/h] on 0 % grades is superior for the bottom dump trucks, and
3. Productivity in [t/h] on 10 % grades is approximately equal for bottom dump and rear dump trucks.

From the reviev of trucks on the market the maximum truck size has probably been reached. Future development is expected to concentrate on refinements to existing models, or filling the gaps between existing models.

For example, higher capacity mechanical transmissions have become available on Komatsu 145 t capacity trucks, a new electric wheel motor was introduced by General Electric for trucks up to 190 t, Kress is offering an unique 2 axle, 145 t capacity truck and DJB is marketing smaller three axle, articulated rear dump trucks. Tires now contain rubber of a new composition with improved wear properties and lower weight. Driver-less truck systems are being studied, trolley assist systems are now proven and operational. Several on-board truck management systems have been introduced and tested on various machines under different mining conditions (Srajer, 1985, 1986).

Articulated trucks are selected using the same logic and projected service requirements as any other off-highway trucks. In addition, articulated trucks are selected for the following reasons:

1. When haul distance exceeds 300 m,
2. When tire costs are excessive due to high ambient temperatures and/or longer hauls, and
3. When hauling lighter weight materials (other trucks would carry insufficient payload).

SELECTION PRACTICES AT THE MINES

Selection practices at the studied surface coal mines generally involve committee work. The mine engineer collects the available information, procures proposals from manufacturers, and presents the findings to senior management for evaluation. The management committee evaluates the engineer's conclusions based on their collective and individual expertise and recommends award of the contract. Personal experience with the line of product offered is often paramount.

Loading equipment is more easily selected than hauling equipment, the decision being based mainly on production requirements, mine conditions and projected usage of the equipment. All contacted mining companies agreed, that they also do not have a great deal of experience in selecting loading equipment. It appears that major loading equipment is usually selected ahead of time by the project engineering group at head office.

Hauling equipment was usually selected by the mining staff at the site after careful and sometimes extensive evaluation. It became apparent during the investigation for this study, that selection practices for loading equipment closely follows the general pattern described earlier in this paper. Selection practices for hauling equipment varies to some extent between mining companies and manufacturers, and are therefore described here in greater detail.

When the mine engineer is asked to select loading and/or hauling equipment, he must first collect all available data concerning projected production capacity, mine haulage, life of the project, and other parameters mentioned earlier in this chapter. In existing mines, the choice is often limited by existing equipment. If this equipment is performing satisfactorily, the same type is usually chosen, perhaps larger or smaller in size. New equipment is usually selected after asking various manufacturers for so called "Application Studies".

Manufacturer's recommendations are evaluated by the mining company and compared on the following bases:

For loading equipment:

-excavator capacity to handle projected quantities,
-experience with similar equipment,
-manufacturer's reputation,
-technical description, such as bucket capacity, digging forces, shoe or wheel selection, etc.,
-working height,
-type of excavator's digging arrangement, whether hoe or shovel,
-possible future use of the equipment, whether production is expected to increase or decrease,
-projected service and maintenance requirements, and
-capital and operating costs.

Each mining company has a computer based evaluating tool, that assigns values to all positive and negative aspects of each proposal. Based on this system evaluation, the appropriate loading equipment is selected.

For hauling equipment:

-match to existing loading equipment,
-capacity to handle projected quantities,
-experience with similar equipment at the mine or elsewhere,
-haulage road suitability,
-service and maintenance requirements,
-capital and operating cost,
-suitability to haul mine material,
-design features, and
-projected availability and utilization of equipment.

Most mining companies have truck evaluation computer programs, to evaluate hauling equipment performance on their own, or to check manufacturers recommendations.

CONCLUSION

In this paper, the selection criteria for shovels, loaders and off-highway trucks, operating at western Canadian coal mines, are discussed. The selection practices of mining companies and equipment manufacturers are also revieved.

The general characteristics of loading and hauling equipment are described to understand their applications, limitations and availabilities. Common practices for assignment of each type of equipment are presented. Guidelines for selection of equipment types to fit existing mining conditions are listed. The design options that may enhance machine performance and make the equipment more applicable to work in western Canadian mines, are discussed for each type of equipment.

The loading shovels used at the selected mines are manufactured by three companies: Demag, Bucyrus-Erie and P&H. The hydraulic excavators are manufactured by Demag, Caterpillar, and Hitachi. The front-end loaders are

supplied by Letourneau, Dart, Caterpillar and Terex. The trucks used for hauling of coal and vaste material at the selected mines are manufactured by Caterpillar, Euclid, Terex, Unit Rig, Kress, Wabco, and Kenvorth.

The selection practices for trucks and loaders at each selected mine are almost identical. The mine contacts equipment manufacturers, describes the requirement for new equipment and asks them for an "Application study". They then collect all available data for projected production capacity, mine haulage, life of the project, and cooperate closely with the manufacturers during their studies. Engineering and operating personnel reviev the various manufacturers bids and recommend/priorize them for senior management reviev. There is strong tendency to select nev equipment similar to that already in use, assuming it has performed satisfactorily.

ACKNOWLEDGEMENT

The authors vish to thank to all mining companies in vestern Canada and all manufacturing companies mentioned in this report for their advice, supply of the information and help in the study.

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